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Short Communication

Anadara granosa (Mollusca: Bivalvia: Arcidae) discovered live in Darwin Harbour, with implications for understanding climate change in northern Australia

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In August 2008, sampling of mudflats on the southern shoreline of Middle Arm peninsula, Darwin Harbour, located an extant population of *Anadara granosa* (Linné), a bivalve mollusc commonly called Roughback Cockle [the FAO name is Granular Ark]. This species occurs in huge quantities in prehistoric shell middens around Darwin, but is now very rare and was thought to be possibly locally extinct. The discovery came out of the need to locate live specimens for comparison with archaeological shells submitted for isotope analysis as part of a larger project 'Climate Change and Human Behavioural Variability in the Coastal Wet-Dry Tropics of Northern Australia'. This collaborative project, being lead by Dr Sally Brockwell of the Australian National University, seeks to explore links between climatic/environmental/ecological/malacological change and the interpretations of major cultural change in the archaeological record in three geographically distinct coastal regions of tropical northern Australia.

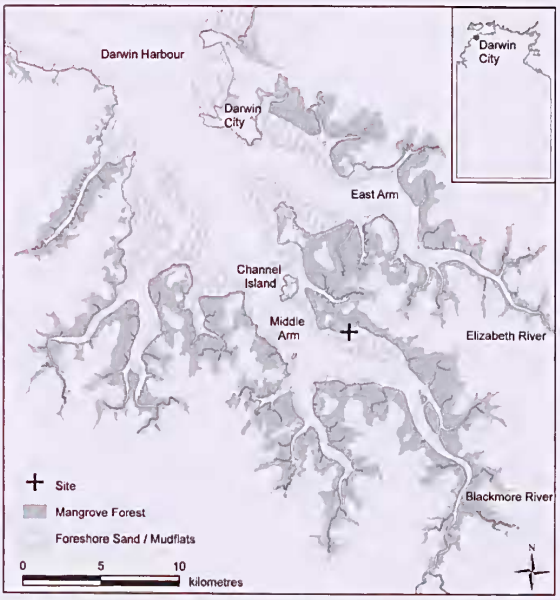

Fig. 1. Location of sampling site, Middle Arm peninsula, Darwin Harbour, Northern Territory. Illustration courtesy M. Fegan.

The site at which the *Anadara granosa* (hereafter *Anadara*) were located is on the shoreline of Middle Arm, the largest sub-estuary of Darwin Harbour (Fig. 1), fed mainly by the Blackmore River with freshwater flows during the wet season. This site, in an embayment on the Middle Arm mainland downstream of Channel Island, was chosen because of the relatively easy access to mudflats close to existing Aboriginal shell middens that are dominated by *Anadara* shells. These tidal mudflats are mainly formed from intertidal marine alluvium, mud, clay and silt (Pietsch 1986; Michie 1988).

Access to the site was gained through the wide mangrove forest that today fringes much of the Harbour (Brocklehurst and Edmeades 1996) via a low rocky ridge extending to an oyster-dominated (*Saccostrea cucullata* (Born)) reef at the seaward edge. The main mangrove species observed on this tidal mudflat are *Rhizophora stylosa* Griff. in the central zone and *Sonneratia alba* Smith in A. Rees on the seaward fringe. The area is generally undeveloped, apart from an aquaculture farm that presently operates some two kilometres south of this site.

The site was sampled on 5 and 22 August 2008, in the second half of the seven month long dry season that characterises Darwin's monsoonal climate. Sampling on both occasions was conducted over an area of approximately 10 m^2 and over approximately 1.5 hr on a spring low tide (Fig. 2). One adult *Anadara* (shell length 36.1 mm) was found live on the first occasion (Fig. 3). On the second occasion, four live adults (shell lengths 47.3, 43.6, 39.0, 51.6 mm) and one freshly dead *Anadara* with conjoined valves (shell length 49.8 mm) were found. Of this total of six live/fresh *Anadara*, three were located at the surface and three were buried 6–10 cm down in very soft fine black silty mud that was 80–90 cm deep and contained abundant disarticulated dead valves of *Anadara* and *Placuna placenta*.

Fig. 2. M. Fegan thigh-deep in mud at sampling site. Note pneumatophores of *Sonneratia alba* in foreground. Photo. R.C. Willan.

Fig. 3. Ventral view of live *Anadara granosa* individual (NTM P.41871) photographed soon after collection. Photo. R.C. Willan.

When collected, and immediately thereafter, the *Anadara* were crawling very actively, indicating the probability of considerable movement within the substrate when alive. Following fixation in absolute ethanol enabling future genetic analyses, all the animals were dissected from their shells and deposited in the mollusc collection of the Museum and Art Gallery Northern Territory under the registration numbers P.41871 (for the specimen collected on 5 August) and P.41930 (for the specimens collected on 22 August). The shells themselves were then sent overseas for isotope analyses. The results of this analysis will be compared with the results of isotope analysis of archaeological *Anadara* shells sampled from radiocarbon-dated shell mounds during excavations in 1996 on the same section of southern shoreline of Middle Arm peninsula and from Hope Inlet, Shoal Bay.

Since no study has been conducted on the growth of *Anadara* in northern Australia we do not know precisely how old these individuals from Darwin Harbour might be. In India, Narasimhan (1968) reported that *Anadara* reaches 31.5 mm shell length after one year, 49.5 mm after two years, and attains sexual maturity at seven months old.

Valves of *Anadara* dominate prehistoric shell mounds around Darwin Harbour (Fig. 4), suggesting large populations once existed that must have been easily exploited by the local inhabitants. All *Anadara*-dominated mounds that have been radiocarbon dated thus far belong to the pre-European period, formed mainly between 1500 and 500 years BP (Bourke 2004; Bourke and Crassweller 2006). *Anadara*, whose preferred habitat is mudflats in protected bays and estuaries (Poutiers 1998; R.C. Willan pers. obs.), no longer occurs in any significant quantity in the Darwin coastal environment of extensive mangrove-colonised tidal flats, suggesting extirpation through local environmental change (Hiscock 1997). Cessation of the *Anadara* mound building period across the northern Australian coast by 500 years BP also suggests regional climatic/environmental change (Bourke *et al.* 2007). While it may have declined in abundance, people continued to harvest *Anadara* after the mound-building period ceased. Local Aboriginal people in the Darwin area report that when they were children (some 30–40 years ago) they knew of areas supporting enough *Anadara* to collect a couple of buckets (Bill Risk pers. comm.), but that even this quantity has declined in recent years.

By contrast, today the most common edible molluscs associated with mangroves in Darwin Harbour are the gastropods *Telescopium telescopium* (Linné) (family Potamididae), *Terebralia* spp. (family Potamididae) and *Nerita balteata* Reeve (previously known as *N. lineata* Gmelin, but this name is preoccupied) (family Neritidae) (Smith *et al.* 1997; Bourke and Willan pers. obs.). These gastropods occur only in small numbers in the shell mounds around Darwin. Significantly, these species of molluscs, together with others – of Potamididae and Ellobiidae, and bivalves of the family Corbiculidae – that occur sympatrically with them, are euryhaline and much more tolerant of long temporal extremes and wide fluctuations in salinity and temperature than stenohaline mudflat bivalves such as *Anadara* (Healy and Wells 1998; Peterson and Wells 1998; R.C. Willan pers. obs.).

While *Anadara* is known to tolerate a range of physical environmental factors, proliferation to abundance does require an optimal habitat setting. Shore elevation, slope of the seabed and substrate type are some known factors that affect successful *Anadara* recruitment, growth and population stability (Broom 1985). Studies elsewhere in the Indo-Pacific have established that the highest population densities of *Anadara* occur in the fine soft brackish muds of open intertidal mudflats bordering, but not within, mangrove swamps and near, but not in, the mouths of large rivers (Broom 1982, 1985; Pathansali 1966). These habitats provide the optimal conditions of soft brackish (salinity between 26 to 31 ppt) fine silt-mud substrate, intertidal or marginally subtidal elevation level with a particular slope of seabed, and

Fig. 4. Typical *Anadara*-dominated prehistoric shell midden on Middle Arm peninsula coast near sampling site. Photo P.M. Bourke.

temperature of 25 to 32°C (Broom 1982:136–7; Pathansali 1966:91). Broom (1982: 137–138) noted that in *Anadara* beds on Malaysian mudflats there was a black sulphide-rich layer 3–4 cm below the surface, and comments that sandier substrates represent a suboptimal habitat for this species.

Of particular interest to us is the distinct difference between the habitat of the modern *Anadara* reported here for Darwin Harbour and that reported for *Anadara* collected by the Anbarra people of the Blyth River area of central Arnhem Land in the 1970s. As noted above, the fine silty black mud of these Middle Arm mudflats is 80–90 cm deep. Collection of the five live *Anadara* was extremely difficult and physically exhausting in this habitat, requiring ploughing through thigh-high mud (Fig. 2) for over two hours. This is in sharp contrast to the Blyth River habitat, where *Anadara* is collected from much sandier mudflats: "gatherers remain upright and mobile, moving over large areas during one session" ... and ... "Groups of women and children ... rove slowly over the area containing *A. granosa*, pausing to dig out a shell, when one is sighted, with their fingers, a digging stick or a file". In 80 minutes on 16 August 1972, 37 kg of *Anadara* (approximately 1000 individuals) were collected by this method (Mechan 1982: 97).

It is known that *Anadara* can recruit to a range of (muddy to muddy-sandy) substrates in sheltered habitats, but it appears that peak settlement – or peak survivorship – only occurs on muddy sand flats that fall within a restricted range of silt/clay fraction/particle size of the substrate (cf. Broom 1985: 5). More research is needed to explore the role played by other factors in the decline of *Anadara* in this region, such as possible increasing extremes in range of salinity and temperature conditions.

Our observations of low densities of living *Anadara* are in accord with evidence for ongoing progradation of mudflats and subsequent colonisation by mangroves in the Darwin region (Woodroffe and Grime 1999: 319). In fact, the specimens we collected may be existing/surviving in a suboptimal habitat in the face of an accreting shoreline and seaward mangrove growth, as has been observed to rapidly encroach on *Anadara* culture sites on a Malaysian foreshore (Macintosh 1982: 13).

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